

DEVELOPMENT OF A DYNAMIC SIMULATION MODEL TO ESTIMATE POPULATION MORTALITY EFFECTS RESULTING FROM THE AVAILABILITY OF SMOKELESS TOBACCO PRODUCTS

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ABSTRACT

Purposes: Potential harm reduction resulting from smokeless tobacco (ST) use has received considerable attention. We are developing a model to estimate changes in future population mortality due to availability of ST that is expected to improve upon previous models.

Methods: We used the WinBUGS computer program to create a simulation that estimates mortality for a hypothetical population of persons who have never used tobacco and who, as they age, may transition into and out of tobacco exposure states, including current and former smoking or ST use. Markov Chain Monte Carlo techniques were used to estimate the variability of the results. All model inputs, including age-specific transition probabilities, are specified by the user.

Results: The model allows for 15 possible transitions into and out of tobacco exposure states, tracks individual exposure histories, and estimates age- and exposure-history-specific all-cause or cause-specific mortality. At each age and at the end of follow-up, the model estimates the number of survivors under two different assumptions—that ST is either available or unavailable—and calculates the difference between the two results. Estimated deaths under the baseline exposure scenario (no ST) closely approximate recent US mortality based on CDC lifetable data. Some alternative exposure scenarios showed benefits from the introduction of ST.

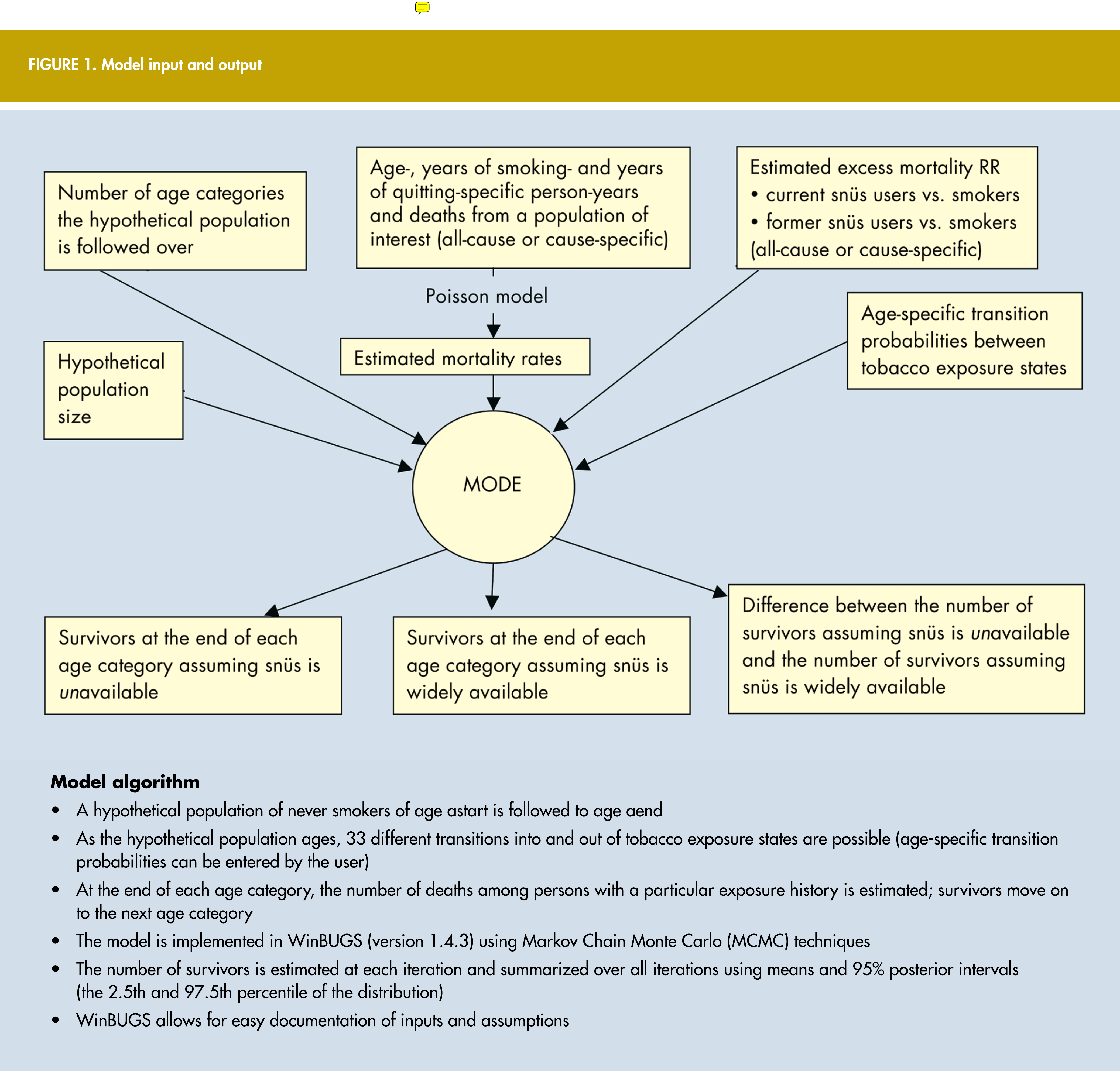
Discussion: The simulation model was developed to use and document any inputs and any defined baseline exposure scenario. We expect models such as this one to be informative for development of harm reduction policies.

BACKGROUND

Cigarette smoking causes numerous serious diseases (Thun et al., 2000). Risk appears to depend on the type of tobacco product and associated toxicant profile (Zeller and Hatsukami, 2009), with combustion-related toxicants the likely source of most of the hazard. Smokeless tobacco (ST) products eliminate exposure to combustion and yield lower exposure to tobacco-related toxicants (Royal College of Physicians, 2007; Hatsukami, 2007; Savitz et al., 2006). If ST replaces some or all cigarettes consumed by individuals, population level harm, measured by total number of tobacco-related deaths, may be reduced. Conversely, increasing availability of ST may dissuade some who may have given up tobacco from doing so, and others may use ST instead of remaining as non-users. **Purpose:** To create a comprehensive model that estimates the changes in mortality at the population level when proportions of potential or actual cigarette smokers switch from traditional cigarettes to ST.

METHODS

- The harm reduction model estimates the all-cause (or cause-specific) mortality expected under different hypothetical distributions of tobacco exposure (different products used with different frequency)
- It compares the number of survivors among different exposure scenarios to assess the hypothetical effect of changes in tobacco use
- To develop and test the model algorithms, we used snüs to represent all ST products



Model algorithm

- A hypothetical population of never smokers of age *a*start is followed to age *a*end
- As the hypothetical population ages, 33 different transitions into and out of tobacco exposure states are possible (age-specific transition probabilities can be entered by the user)
- At the end of each age category, the number of deaths among persons with a particular exposure history is estimated; survivors move on to the next age category
- The model is implemented in WinBUGS (version 1.4.3) using Markov Chain Monte Carlo (MCMC) techniques
- The number of survivors is estimated at each iteration and summarized over all iterations using means and 95% posterior intervals (the 2.5th and 97.5th percentile of the distribution)
- WinBUGS allows for easy documentation of inputs and assumptions

Possible transitions between tobacco exposure states

- remaining a never-tobacco user until the end of follow-up
- use of only cigarettes
 - cigarette use until the end of follow up
 - cessation
 - cessation & recidivism
 - cessation, recidivism & 2nd cessation
- use of only snüs¹
 - snüs use until the end of follow up
 - cessation
 - cessation & recidivism
 - cessation, recidivism & 2nd cessation
- snüs use followed by cigarette use¹
 - cigarette use until the end of follow up
 - cessation of all tobacco use
 - switching back to snüs; then using snüs until the end of follow up
 - switching back to snüs; then cessation of all tobacco use
- cigarette use followed by dual use
 - dual use until the end of follow up
 - cessation of all tobacco use
- snüs use followed by use of snüs and cigarettes (dual use)¹
 - dual use until the end of follow up
 - cessation of all tobacco use
- snüs use followed by dual use
 - dual use until the end of follow up
 - cessation of all tobacco use

- cigarette use followed by snüs use²
 - snüs use until the end of follow up
 - cessation of all tobacco use
 - switching back to cigarettes; then using cigarettes until the end of follow up
 - switching back to cigarettes; then cessation of all tobacco use
- snüs use followed by use of snüs and cigarettes (dual use)¹
 - dual use until the end of follow up
 - cessation of all tobacco use
- cigarette use followed by dual use
 - dual use until the end of follow up
 - cessation of all tobacco use

¹ among persons who would not have used any tobacco and among persons who would have used cigarettes in the absence of snüs
² among persons who would have continued cigarette use and among persons who would have quit cigarette use in the absence of snüs

Model validation

- Using Excel, the model was checked “by hand” through 7 age categories. This encompassed all modeled transitions.
- Model based** estimates of age category-specific survivors (assuming no snüs use) were compared to the 2006 US life table.
- Model based** estimates of age category-specific survivors (assuming Swedish snüs use patterns based on Ramström and Foulds, 2006) were compared to the 2006Swedish life table.

Examples

To illustrate the model, we created a hypothetical population of 1,000,000 people and 3 hypothetical scenarios. In each scenario we assumed that among existing cigarette smokers the decision to switch to snüs or to initiate dual use was affected by health concerns and ease of use in public places.

SCENARIO 1: *Snüs is a gateway for cigarette smoking*; the majority of never tobacco users initiating snüs eventually switch to cigarette smoking.

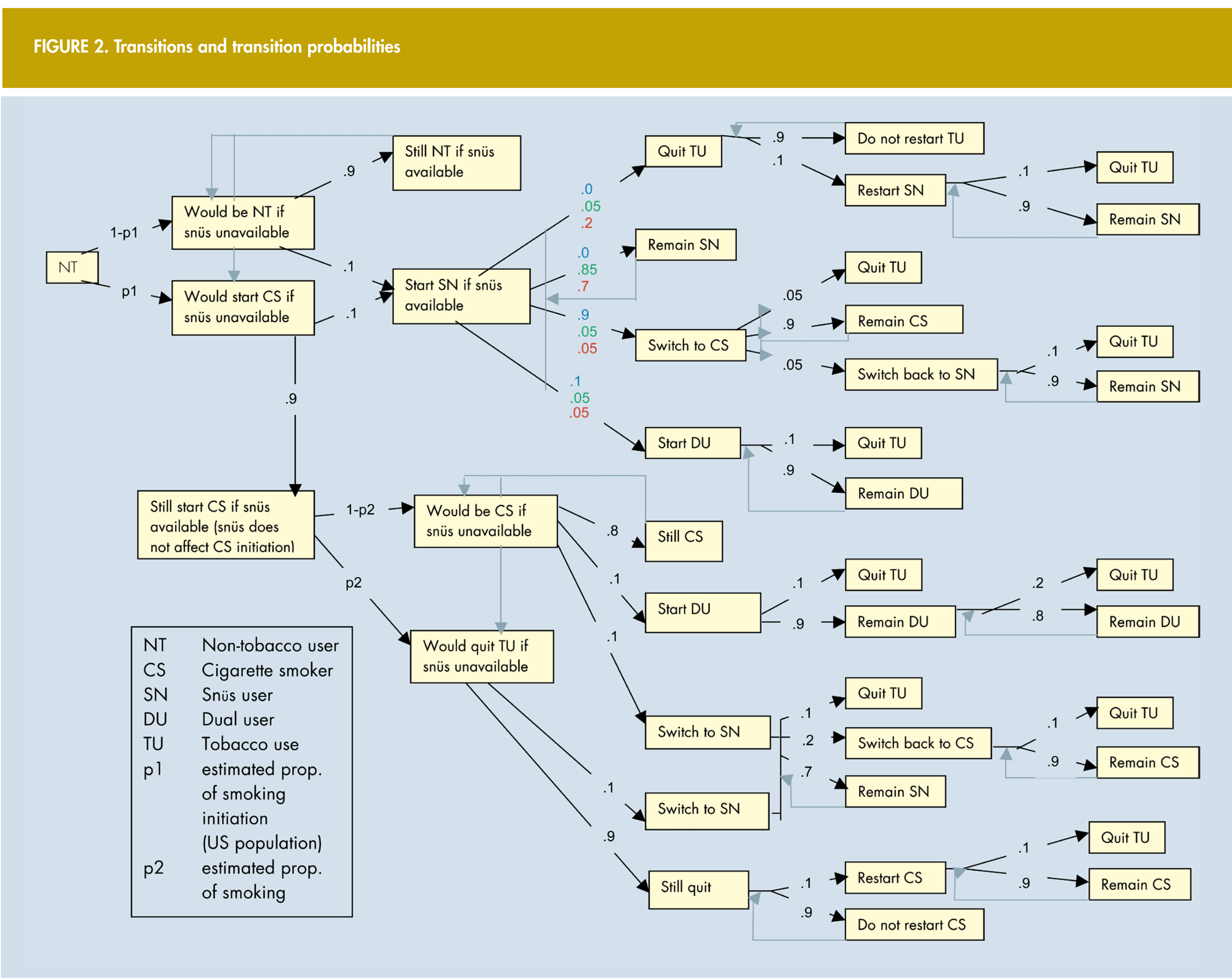
SCENARIO 2: *Snüs is not a gateway for cigarette smoking but snüs cessation is uncommon*; the majority of never tobacco users initiating snüs never switch to cigarette smoking, but few snüs users quit.

SCENARIO 3: *Snüs is not a gateway for cigarette smoking and snüs cessation is common*; the majority of never tobacco users initiating snüs never switch to cigarette smoking and many snüs users quit.

The transition probabilities are shown in figure 2.

Follow-up started at age 13 and ended at age 72. Age category-specific smoking initiation rates for 1980 were obtained from the National Household Survey on Drug Abuse. Office of Applied Studies, 1999 (p1 in figure 1). We used 11.25%, 10%, 1.25% and 0.25% for age categories 13-<18, 18-<23, 23-<28 and 28-<33, respectively, and 0 for older age categories. Age category-specific smoking cessation rates for 1980 were based on data from *The California Tobacco Control Program's effect on adult smokers: (1) Smoking cessation*. (Messer K et al., 2007, p2 in figure 1). We used 2.5% for the youngest age category, 4.5 for the next older 3 age categories, 5.0 for category 33-<38, 5.5 for categories 38-<43 and 43-<48, 7.5% for category 48-<53 and 8.5% for the remaining 4 age categories. For simplicity, all other transition probabilities were kept constant over the 12 age categories with one exception. For ages less than 43, the probability of snüs initiation was 0.1 while for ages 43 and older the probability of snüs initiation was 0.

Age-, years of smoking- and years of quitting-specific mortality rates were based on the coefficients from a Poisson model using data from the Kaiser Permanente Cohort study. The excess RR for current snüs users vs. smokers (0.8) was based on an estimate by Levy et al., and the excess RR for former snüs users vs. smokers was set to 0.5. Certainty in the accuracy of the model input was considered to be low. A Markov chain was considered to have converged if the Monte Carlo error was less than 5% of the sample standard deviation; in most cases, 1000 iterations preceded by a burn-in of 600 iterations was sufficient.



RESULTS

Tables 1 and 2 suggest very close correspondence between the lifetable based numbers of survivors and the model based estimates for both the US and Swedish populations.

TABLE 1. Comparison of 2006 US life table based number of survivors to model based estimated number of survivors (assuming no snüs use) ¹		
Age category	Survivors based on US Life Table	Survivors based on Model
38-42	968,540	966,900
43-47	959,460	957,200
48-52	945,735	944,400
53-57	925,510	926,700
58-62	897,045	901,300
63-67	856,540	863,700
68-72	799,560	805,600

¹ Age group 38-42 is the 1st age group where all possible transitions have occurred

TABLE 2. Comparison of survivors based on the 2006 Swedish life table to model based estimates of survivors (assuming Swedish snüs use patterns) ¹		
Age category	Survivors based on US Life Table	Survivors based on Model
38-42	985,160	982,500
43-47	980,800	976,300
48-52	973,950	967,800
53-57	962,270	955,700
58-62	943,345	937,800
63-67	913,945	910,500
68-72	868,770	868,000

¹ Age group 38-42 is the 1st age group where all possible transitions have occurred

Table 3 shows that the effect on population mortality of widespread availability of snüs depends on the tobacco use patterns.

TABLE 3. Mean difference and 95% posterior intervals between the numbers of survivors at the end of follow-up assuming snüs is unavailable (status quo) and assuming snüs is widely available			
Scenario among SN initiators who never smoked	Approximate mean difference between # survivors; scenario vs. status quo	Approximate 95% posterior interval	
Snüs is a gateway for cigarette smoking	80	(-8200, 8900)	
Snüs is not a gateway for cigarette smoking; snüs cessation uncommon	7000	(2700, 11,000)	
Snüs is not a gateway for cigarette smoking; snüs cessation common	14,000	(8300, 20,000)	

We also considered the four scenarios modeled in a recent study (Meija et al., 2010): successful aggressive snüs promotion; successful aggressive snüs promotion with most snüs users from smokers; modest success in snüs promotion; and no effect of snüs on initiation. We based our transition probabilities and comparative risk estimates on those used by Meija et al. Our results agreed with their findings of no significant population level benefit in any scenario vs. status quo.

DISCUSSION

The effect on the population mortality of widespread availability of ST depends heavily on the tobacco use patterns and underlying comparative risk estimates. Our scenarios as well as the scenarios considered by Meija et al. were based on extreme tobacco use patterns; results should not be used to draw conclusions about likely population effects of widespread availability of ST.

Strengths

- 33 possible transitions between tobacco exposure states including dual use and recidivism
- Estimates the number of survivors at the end of each age category for each exposure history up to that point
- No restrictions on age or on time of initiation or cessation of a tobacco product
- Mortality rate estimation can be based on years of smoking or on cigarette years depending on the availability of population data
- Model can be calibrated to take into account the background mortality rate in the population of interest
- All model input can be changed easily by the user
- Level of uncertainty in model input can be specified and is taken into account
- Estimates of the variability of the results are calculated
- Model has been tested extensively

Limitations

- Results can be very imprecise if certainty in the model input is low
- Most transition probabilities are unknown (however, some transition probabilities may be known in the future; for now, values can be chosen to model hypothetical extreme and moderate scenarios)
- Not all possible transitions can be modeled (however, this model captures the exposure history of most of the population)

CONCLUSIONS

We created a comprehensive model that estimates the changes in mortality at the population level when proportions of potential or actual cigarette smokers switch from traditional cigarettes to ST. The model incorporates the most commonly seen tobacco exposure histories and all model input is chosen by the user. The model can be easily adapted to investigate alternative assumptions about exposure distributions, probability of transition between exposures, and the comparative risks associated with different products. It can also be used to evaluate specific causes of death and to include additional or alternative products. As empirical data become available, the model will become more useful in its ability to inform policy decisions. At present, most of the assumptions of the model, and thus the model-generated estimates, are highly uncertain.

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